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5

Dealing with complications in laparoscopy

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With increasing adoption of laparoscopic surgery in gynaecology, there has been a corresponding rise in the types and rates of complications reported. This article sets out to classify complications associated with laparoscopy according to the phases of the surgery; assess the incidence, the mechanisms, the presentations; and recommend methods for preventing and dealing with complications in laparoscopic surgery. Its aim is to promote a culture of risk management based on the development of strategies to improve patient safety and outcome.

In the modern history of laparoscopy, the momentous transition from diagnostic to operative laparoscopic procedures accelerated following the first report of laparoscopic hysterectomy in the late 1980s.[1] Since then, there has been a rapid worldwide adoption of increasingly complex laparoscopic procedures across many surgical specialties, most notably in gynaecology.[2,3] Unfortunately, the increased adoption of laparoscopic surgery has also been accompanied by a corresponding rise in the rates and types of complications reported.[4–9]

'Complication' is defined in the Oxford English Dictionary as "a new problem or illness that makes treatment of a previous one more complicated or difficult".[10] Complications to laparoscopy are similar to

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side-effects to medications. While uncommon, both inevitably occur, often at the least expected time and in the least expected situation. This article sets out to classify complications associated with laparoscopy according to the phases of the surgery; assess the incidence, the mechanisms, the presentations; and recommend methods for preventing and dealing with complications in laparoscopic surgery.

Classification of complications

Rather than approaching the many different types of complications in laparoscopy as isolated events, we propose that they be classified according to the phases of the procedure:

- Phase I – Patient identification
- Phase II – Anaesthesia and positioning
- Phase III – Abdominal entry and port placement
- Phase IV – Surgery
- Phase V – Postoperative recovery
- Phase VI – Counselling

The aim of this phase-based classification is to promote a culture of risk management based on the development of strategies to improve patient safety and outcome[11], the underlying principles of which can be remembered by the acronym of **ACT**:

- ***Awareness*** that a complication can occur at ***any time*** before the patient enters the operating room through to the postoperative phase.
- ***Communication*** and ***counseling*** skills are essential in preventing and dealing with complications.[12]
- ***Teamwork*** and ***training*** are important risk management principles in protecting and ensuring patient safety from harm, particularly in laparoscopic surgery due to the frequent introduction of new technologies or techniques.[13,14]

Let us now see how the ACT risk-management principles can be applied to prevent and deal with complications which may occur during the various phases of laparoscopic surgery.

Phase I – Patient identification

It is the responsibility of the surgical team to go through the routine of checking the patient identity, consent form, listed procedure, site of surgery and whether a patient has an allergy before the patient is anaesthetised. Failure to complete this basic step may cause grievous harm and complications in laparoscopic surgery before an incision is made.[15–18]

Phase II – Anaesthesia and positioning

Laparoscopic surgery presents unique anaesthetic challenges which are not seen in open surgery. These include the effects of pneumoperitoneum, patient positioning, extraperitoneal gas insufflations and venous gas embolism.[19]

Pneumoperitoneum

The creation of pneumoperitoneum can cause both immediate as well as dynamic cardiopulmonary effects. Initial gas insufflation may result in pronounced bradyarrhythmias and even asystole as a result of vasovagal reflex from peritoneal stretch.[20,21] This needs to be differentiated from intravascular gas insufflations, intra-abdominal blood loss from vascular injury or anaphylactic reactions. The release of pneumoperitoneum, with or without administration of short-acting adrenergic drugs such as atropine or adrenaline, should result in rapid reversal of the bradycardia, and may be followed by re-insufflation at a slower rate.

Once the procedure is underway, the continuing raised intra-abdominal pressure can cause a reduction in venous return via the inferior vena cava and a rise in systemic vascular resistance

(SVR). These changes can result in a fall in cardiac output (CO). Pneumoperitoneum may also affect lung mechanics causing a significant reduction in compliance and increase in airway pressures. Alterations in lung unit ventilation–perfusion (V/Q) ratios can lead to increased mismatching and consequent effects on O_2 and CO_2 blood concentrations, notably hypoxaemia and hypercarbia (Table 1).

Patient positioning

The Trendelenburg position further impacts on the haemodynamic and pulmonary consequences of pneumoperitoneum. While the head-down position may partially offset the changes to venous return, SVR and CO, it may lead to a number of pulmonary effects such as a decrease in vital lung capacity and increase in airway pressure caused by cephalad movement of abdominal viscera onto the diaphragm. The endotracheal tube may slip into the right bronchus with the cephalad shift of the trachea carina. Prolonged Trendelenburg positioning may lead to a significant increase in central venous pressure and cause central and cerebral venous congestion.

To counter the cardiopulmonary effects of Trendelenburg position and pneumoperitoneum, the intra-abdominal pressure should be kept to less than 15 cm of water and ventilation pressures to less than 30 cm of water while maintaining adequate minute ventilation and minimising duration of surgery to decrease cerebral venous congestion.

Extraperitoneal gas insufflation

CO_2 under pressure can pass through pericardial and pleural spaces through anatomic, congenital paths or acquired diaphragmatic defects. Significant extraperitoneal gas insufflations can lead to pneumomediastinum, pneumopericardium and pneumothorax. Similarly, CO_2 can pass retroperitoneally through vast potential spaces causing subcutaneous emphysema (Fig. 1).

Intra-operative treatment of extraperitoneal CO_2 insufflation includes the use of positive end-expiratory pressure (PEEP), increased minute ventilation to open collapsed alveoli, increased pressure to decrease the abdominal pressure gradient (or decrease abdominal pressure) to splint or seal the defect. Postoperatively, entrapped CO_2 gas will diffuse out using treatment with 100% oxygen and adequate ventilation in an upright sitting position.[22]

CO_2 embolism

This rare but dramatic complication can lead to sudden cardiovascular collapse, profound neurological deficit and is associated with a mortality rate as high as 28.5%.[23] The incidence varies from 0.001% to 0.59% of cases.[24] This complication may occur soon after commencement of gas insufflations and is due to direct intravascular gas entry into the arterial or venous system.[23]

Table 1
Pneumoperitoneum: physiological effects and management.

Physiological Effects	Pre Pnperitoneum IABP -NIL	Post Pnperitoneum IABP 15–20 cm H_2O	Management
Cardiovascular			
- SVR	⬆	⬆⬆	
- SBP/DBP	⬆	⬆⬆	Short acting anti adrenergics
- HR	⬆	⬆⬆	Increase intravascular fluids
- Cardiac Function	⬌	⬇	
Respiratory			
- Peak Inspiratorypressure	⬌	⬆⬆	Add PEEP pressure
- Lung compliance	⬌	⬇	Increase FiO2 level
- V/Q mismatch	⬆	⬆⬆	

⬌ Unchanged, ⬆ Increased, ⬇ Decreased.

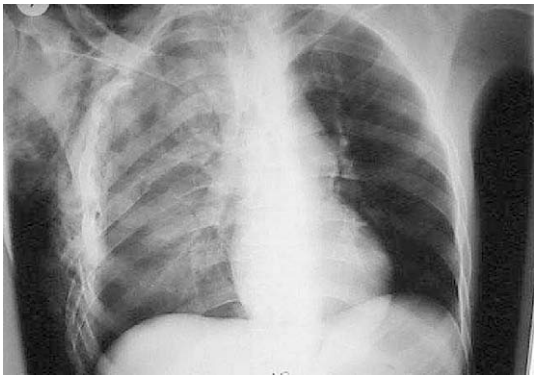

Fig. 1. CXR shows pericardial, pneumomediastinal and subcutaneous emphysema following laparoscopic gynaecological procedure. Permission from Liew A.

Small amounts of CO_2 embolism may be inconsequential as CO_2 is highly soluble in blood. However, when large volumes of gas are lodged directly onto the pulmonary outflow trunk, this can lead to increases in pulmonary arterial pressure (PAP), increased resistance to right ventricular outflow and diminished pulmonary venous return. The consequent decrease in left ventricular preload results in diminished CO, asystole and systemic cardiovascular collapse.[25] In addition, the alteration in the resistance of the pulmonary vessels and VQ mismatch cause intrapulmonary right-to-left shunting and increased alveolar dead space, leading to arterial hypoxia and hypercapnia.[26] Studies in dogs have shown that the median lethal dose of CO_2 embolism is 25 ml kg^{-1}, which amounts to about 1750 ml of CO_2 or 375 ml of air in a 70-kg person.[27]

Diagnosis on clinical grounds can be difficult since presentations seen with gas embolism (hypotension, hypoxia, decreased end-tidal carbon dioxide) can be caused by other complications such as anaphylaxis, pneumothorax, coronary events and haemorrhage.[28] In any event, initial resuscitation must include communication with the surgical team, release of pneumoperitoneum and basic life-support measures. In doing so, hopefully time and additional assistance will allow for investigation of the specific cause (Fig. 2).

Phase III – Entry-related complications

Laparoscopy involves gaining entry into the abdomen for gas insufflation and insertion of primary (most commonly at the umbilicus) and secondary trocars. It has been estimated that more than 50% of all complications associated with laparoscopy occur during the abdominal entry phase.[8] The potential complications include vascular, intestinal, urinary tract injury and gas embolism.

Phase IV– Surgery-related complications

Besides the general surgical risks associated with any intra-abdominal surgery, there are specific risks to the type of surgery being performed and the type of pathology for which it is being performed. For example, the main risk associated with adhesiolysis is intestinal injury[29], for myomectomy it is haemorrhage[30], while the main risk with hysterectomy and removal of an entrapped ovary is urinary tract injury.[31]

Phase V– Postoperative phase

Complications such as bowel, urinary tract injuries or secondary haemorrhage may not present until the postoperative phase. Awareness and vigilance are critical as delayed diagnosis and/or inappropriate intervention may result in serious morbidity or even mortality.

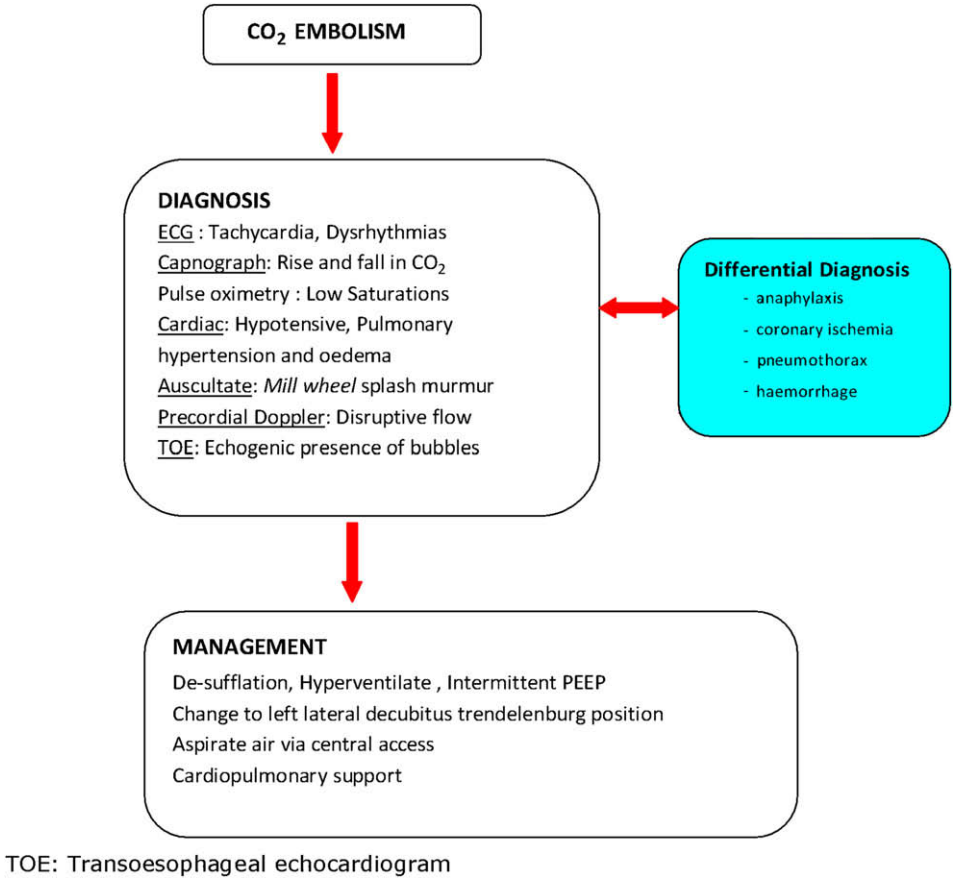

Fig. 2. CO_2 embolism: Diagnosis and Management.

Vascular, intestinal and urinary tract complications may occur during the entry phase, the surgery phase or in the postoperative phase. These specific complications will now be examined in detail and measures to guard against and/or to deal with such complications will be presented.

Vascular injury

Incidence

Vascular injuries are undoubtedly the most alarming and serious laparoscopic complications with a 9–17% mortality rate.[32,33] The reported incidence varies from 0.04% to 0.5% of all laparoscopies.[7,34] A recent study by the Swiss Association of Laparoscopic and Thoracoscopic Surgery examining 43,028 laparoscopic procedures reported a 1.7% intra-operative and a 1.5% postoperative incidence of internal bleeding or haematoma of the abdominal wall, and a 0.09% incidence of major vascular injuries.[35] This suggested that the actual incidence of vascular injuries in laparoscopy may be under reported.

Sites and mechanism of injury

Most vascular injuries occur during insertion of the Veres needle or the trocar.[7] The proximity of the distal aorta and the right common iliac vessels to the umbilicus put them at higher risk of injury than the

inferior vena cava, the left common, the internal and external iliac vessels.[36–38] Vascular injuries have also been reported with the Hasson open entry, direct entry and insertion of secondary trocars.[7,39,40]

Bleeding on aspiration of the Veres needle or through the trocar, frank or concealed bleeding within the pelvis or abdomen and unexplained hypotension should warrant exploration and identification of the bleeding vessel immediately. Due to delayed recognition, vascular injury during the entry phase is associated with greater morbidity and mortality than injury during the surgical phase of a laparoscopic procedure.[37]

Significant bleeding can also arise from injury to the superficial epigastric, superficial circumflex, inferior epigastric or deep circumflex vessels from insertion of secondary trocars.[41,42] The bleeding may present as a diffuse haematoma within the abdominal wall or profuse haemorrhage into the peritoneal cavity. At times, port-site bleeding may be tamponaded by the trocar and seems minimal during surgery but may present during the postoperative phase.[43]

Prevention

Risk factors contributing to major vascular injury include the surgeon's skill, instrument sharpness, angle of insertion, patient position, degree of abdominal wall elevation and volume of pneumoperitoneum.[44] To eliminate these risk factors and to avoid entry-related vascular injury, the authors use a standardised entry technique that involves:

- Abdominal wall elevation while making a 1-cm vertical incision through the skin, the rectus sheath and the peritoneum at the umbilicus
- Abdominal wall elevation while inserting a blunt or dilating tip trocar through the abdominal wall incision
- Insufflation only after confirmation of correct placement of the laparoscope

The insertion of the secondary trocars is always under direct vision to avoid injuring the vessels in the abdominal wall and the pelvic sidewall. The superficial epigastric and the superficial circumflex iliac vessels can be identified by transillumination while the inferior epigastric vessels can be traced by direct visualisation of the anterior abdomen.

Management

Vascular injury requires prompt, directed and coordinated response.[45] The authors use the acronym **SAAS** for dealing with vascular injury:

- **S**top the arterial bleeder immediately by occluding the vessel with atraumatic grasping forceps, or tamponading diffuse venous bleeding with a 2-inch vaginal pack inserted through a 10–12-mm port or through a laparotomy incision. Do not inadvertently extend the tear or blindly coagulate with bipolar diathermy forceps.
- **A**lert the team so that resuscitation measures (intravenous (IV) access, blood cross-matching, volume replacement and blood transfusion) can be commenced while a laparotomy tray and, if required, help from a vascular surgeon can be obtained.
- **A**ccess the bleeding site by the quickest and safest route. This usually means conversion to laparotomy.[35,46] The laparoscopic approach may be considered if the patient is haemodynamically stable, the injured vessel is clearly located, the bleeding temporarily controlled and the surgeon is experienced in handling such injury.
- **S**ecure the vascular injury by using an appropriate haemostatic method according to the nature of the injury (Table 2).

Intestinal injury

Incidence

The incidence of intestinal injuries increases from 0.06 to 0.5% for diagnostic laparoscopy to 0.3–0.5% in operative laparoscopy.[50] While relatively uncommon, intestinal injuries can result in

Table 2
Proposed management of vascular injuries.

Nature of vascular injury	Proposed haemostatic methods
Isolated arterial bleeding	Bipolar diathermy, vascular clips, suture
Large vessel injury	Graft eg. omentum, rectus sheath, synthetic graft, or vascular stapler[47]
Peg-hole injury	Figure of 8 suture
Presacral vessels	Thumbtacks
Diffuse capillary bleeding	Hemostatic sponge (gelatin, cellulose or microfibrillar collagen, or components of the clotting cascade as thrombin and fibrin[48,49]
Abdominal wall bleeders	Bipolar diathermy, inflated Foley's catheter balloon, ligation using a port closure instrument (the Carter- Thomason CloSure, Inlet Medical Inc, Eden Prairie, MN, USA or the Endoclose, Autosuture, Norwalk, CT, USA), a cut-down and suture ligation

serious complications including death following laparoscopy.[33] In a review of 31 papers published between 1973 and 2001 examining 329,935 laparoscopic procedures, the mortality rate from laparoscopy-induced bowel injury was as high as 3.6%.[51]

Mechanisms of intestinal injury

The commonest sites of injury are small bowel (58%), colon (32%) and stomach (8%).[52] It is estimated that up to half of all laparoscopy-associated intestinal injuries may happen during the entry phase of laparoscopy from the use of the Veres needle and trocar insertion.[53,54] The remainder may be due to trauma from surgery, thermal injuries from electro-surgery[55], herniation through port sites[56,57] or anastomotic leaks.

The extent of adhesiolysis performed intra-operatively has been found to be a significant risk factor for intestinal injury.[51] An open entry technique has not been shown to reduce the incidence of entry-related bowel complications but may allow immediate recognition of the bowel injuries.[58] Intestinal trauma may result from inappropriate use of grasping forceps, bowel retraction, insertion and re-insertion of instruments or sharp dissection. Thermal injuries during surgery may be caused by direct, capacitive coupling or insulation failure.[55] Such injury may be unrecognised or occur outside the operating field, leading to late presentation and delayed diagnosis.[59]

Herniation through laparoscopic port sites is uncommon, with a reported incidence of 0.06–1%.[56] The risk is related to the size of the trocar with a 3.1% risk associated with 12-mm trocar wounds compared to 0.2% with 10-mm trocar wounds.[57,60] Bowel herniation through 5-mm ports has also been reported.[61,62]

Anastomotic leakage is a rare but serious complication. The leakage rate is related to the level of the anastomosis from the anus.[63] Platell et al. showed that the rate of anastomotic leakage for ultra-low anterior resection, low anterior resection, high anterior resection and hemicolectomy were 8%, 3.2%, 2.3% and 0.4%, respectively.

Prevention (Table 3)

Management

The management of laparoscopy-associated bowel injuries depends on three main factors:

- The timing of the diagnosis
- The patient's clinical status
- The availability of expert assistance

It is estimated that only 30–50% of intestinal injuries are recognised during surgery. The remainder may present any time from 1 to 30 days after surgery.[52] The length of time from surgery to recognition is variable depending on the site and type of bowel injury. Small bowel injuries normally present at 4.5

Table 3
Measures which may help reduce intestinal injuries.

- Routine inspection of the bowel below the entry site
- Minimise bowel handling
- Use atraumatic grasping forceps for bowel handling
- Careful tissue dissection
- Manipulate and dissect under vision
- Limit adhesiolysis to clinically indicated cases only
- Regular inspection of the bowel after removal and reinsertion through the secondary port(s) to ensure that bowel loops are not inadvertently picked up and hung over the instruments
- Limit the use of thermal energy when working close to or on bowel wall
- Periodic checking of laparoscopic instruments for insulation failure

days (range 2–14) while colon injuries 5.4 days (range 1–29).[52] Thermal injuries tend to present late. The reasons leading to delayed presentation of bowel injuries are listed in Table 4.

In general, the later the diagnosis, the higher the morbidity and mortality associated with bowel injury.[52,64]

Patients with laparoscopy-associated intestinal injuries may present with subtle symptoms such as mild abdominal distension, pain at the trocar site near the injured segment, low-grade fever, diarrhoea with normal bowel sounds or mild hypoxia with few peritoneal signs. Respiratory distress may be mistaken for a chest infection or pulmonary embolism. Others may have the classical symptoms of acute abdominal pain, vomiting, tachycardia, hypotension, abdominal rigidity and ileus.[65] Once peritonitis becomes generalised, the patient's condition may deteriorate quickly with a risk of chest consolidation, sub-diaphragmatic abscess, septicaemia and multi-organ failure.[52]

Management

Early recognition and appropriate intervention is the key to minimising morbidity and mortality associated with laparoscopy-associated intestinal injuries.[64] Faecal contamination at the tip of the Veres needle or trocar, or subtle signs such as bowel-wall haematoma should raise suspicion and require careful inspection of the bowel surface for possible injury. If in doubt, submerging bowel loops under irrigation fluid may reveal air bubbles[66] or bowel content spillage from the bowel defect.[67]

The injured bowel should be repaired immediately. This can be done laparoscopically or by exteriorising the injured loop through a mini-laparotomy.[64,68] Gastric, small-bowel and colonic injuries can be repaired with one or two-layered closure using 4/0 Vicryl or PDS sutures. All non-viable tissue should be excised. The management of all bowel injuries should also include a thorough peritoneal lavage and antibiotic coverage. Early consultation and involvement of the colorectal team are paramount if the gynaecologist does not have the experience or technical ability to deal with bowel complications.

Patients with suspected intestinal injuries in the postoperative period should be promptly admitted for assessment, intravenous rehydration, parenteral antibiotics and insertion of a nasogastric tube. Abdominal radiographs, ultrasound examination, computed tomography (CT) with contrast of the abdomen and pelvis may reveal air under the diaphragm, distended bowel loops with multiple fluid

Table 4
Possible reasons leading to delayed diagnosis of bowel injuries.

- Injury outside the operating field caused by bowel retraction or handling with sharp instruments
- Unrecognized injury on entry or during closure of port sites
- Thermal injury with subsequent bowel wall necrosis and breakdown
- Postoperative abscess with subsequent fistula formation
- Herniation through port sites
- Postoperative narcotic medications masking pain
- Atypical presentation of patients with laparoscopic bowel injury due to different inflammatory and immunological response[52]
- Clinician denial

levels or localised fluid/air collections due to abscesses.[69] However, imaging studies and blood tests should not be used solely to guide clinical decision making as they are not always conclusive. If in doubt, early involvement of other specialists, such as a colorectal surgeon, intensive care specialist, anaesthetist, microbiologist and chest physician, is advised. So is a low threshold for an exploratory laparoscopy or laparotomy if the patient's condition is unclear.

A second-look operation should include a thorough peritoneal lavage and close inspection of the bowel to identify the site of injury. The damaged segment of bowel must be excised with closure of the defect with or without diversion. Where the patient's condition is stable, the patient should be seen, counselled and assessed by a stoma therapist preoperatively. Small-bowel injury may require an end stoma, while large-bowel injuries may require a Hartmann's procedure.[69] Postoperative care should include close monitoring of the patient's condition, gastrointestinal rest with intravenous fluids and total parenteral nutrition, antibiotics and progress monitored with CT scans.

Urinary tract injuries

Incidence

The incidence of urinary tract injury ranges from 0.05% to 8.3% of all laparoscopies. Trauma to the bladder occurs more frequently (0.02–8.3%)[70] than to the ureter (0.5–3%).[71] While injuries to the bladder are easily recognised, injuries to the ureters are frequently missed during surgery. Delayed diagnosis of urinary tract injury is associated with serious morbidity such as fistula formation, peritonitis, loss of renal function and is a frequent cause of medicolegal litigation.[72,73]

Mechanism of injuries

Bladder injury during laparoscopic surgery may occur due to insertion of a suprapubic trocar into a full bladder, bladder dissection during laparoscopic hysterectomy, excision of endometriosis, or removal of pelvic masses such as uterine myoma or ovarian tumours. Conditions which cause distortion of normal pelvic anatomy, such as adhesions from previous caesarean section or radiation, increase the injury risk.[74] The bladder dome is the most common injury site, followed by the posterior bladder base.[70] The mechanisms of bladder injury during laparoscopic surgery include electrocautery, blunt dissection, or trauma from laser, scissors and from trocars.[70]

The common sites of ureteric injury are next to the infundibulopelvic ligament where the ureters cross the pelvic brim, the ovarian fossa, lateral to the cervix where the ureter passes under the uterine arteries, the uterosacral ligament and the anterior vaginal fornix.[75] The mechanisms of injury include transection, ligation or necrosis from energy damage or ischaemia.

Prevention

Prevention of urinary tract injuries requires a detailed knowledge of pelvic anatomy, meticulous dissection skills, use of the avascular surgical spaces and good haemostatic principles.

Bladder injury risk is reduced by routine bladder drainage during surgery, insertion of suprapubic trocars above the bladder dome, sharp rather than blunt dissection of the bladder from the cervix during hysterectomy and an awareness of congenital abnormalities.[76]

The avoidance of ureteric injury requires the ability to identify its course from the pelvic brim to the bladder, the dissection skills to separate the ureter away from the infundibulo-pelvic ligament (before ligation of this pedicle) or during excision of endometriotic implants on the lateral pelvic sidewall and before ligation of uterine vessels during laparoscopic hysterectomy.[77,78]

Management

Bladder injuries

Early recognition and repair of the bladder defect are important to prevent the development of fistulas. Ostrzenski et al., in a review of 1372 articles on laparoscopic surgery published between 1970

and 1996, reported that an intra-operative diagnosis of bladder injury was made in 53.24% of all bladder injury cases.[70] Gilmour found that 97% of postoperatively recognised bladder injuries presented as vesico-vaginal fistulas.[79]

Partial trauma to the bladder can present as a mucosal bulge through the muscularis layer. A complete injury will result in the loss of urine through a hole in the bladder wall. If in doubt, instillation of methylene blue dye into the bladder via an indwelling urinary catheter will confirm whether dye leaks through the defect into the abdominal cavity. Cystoscopy should help evaluate the extent of bladder trauma in relation to the ureteric orifices.

Bladder injuries can be repaired laparoscopically or through a mini-laparotomy with fine, absorbable polydiaxanone or vicryl sutures in one or two layers, with interrupted or continuous closure as long as a watertight repair is achieved. Non-absorbable sutures should not be used as this can result in formation of calculus, granulomas and fistulas. An indwelling urinary catheter should be placed for 7–10 days to promote tissue healing.

Ureteric injuries

Current evidence from the literature indicates that over 70% of ureteric injuries present postoperatively.[71,75,80] Several measures may facilitate an intra-operative diagnosis and decrease the delay in recognition of ureteric injuries. Cystoscopy after giving intravenous indigo carmine dye may raise suspicion of ureteric damage if the ureteric jet is significantly slower or dye-stained urine cannot be visualised from the orifice of the affected ureter. Failure to freely pass a ureteric stent should also raise suspicion of ureteric obstructive injury. Laparoscopy may demonstrate dye leakage through a defect of the ureteric wall. Finally, blanching of a segment of the ureter should alert the surgeon to the possibility of diathermy injury which, if not recognised, may result in necrosis, urinary leakage and urinary peritonitis.

Intra-operative diagnosis of ureteric injuries should allow immediate repair with the help of a urologist. Traditionally, these injuries are managed via laparotomy. However, successful laparoscopic ureteric injury repairs have been reported in the literature where the outcome was similar for both laparoscopy (91.3%) and laparotomy (90.4%)[64,71,73,74,81,82]. Generally, laparoscopic repair is possible as long as the injury is not too close to the bladder and the lesion is less than 1.5 cm.[83]

Where the ureter is ligated or kinked, the offending ligature should be removed immediately and the ureter's integrity assessed by monitoring for peristalsis and colour change. If there is any concern about tissue viability, a ureteric stent should be inserted and the patency checked with an intravenous pyelogram (IVP) 10 days later.[84]

Where the ureter is transected, the repair technique depends on the site and extent of injury. Partial transection can be managed by insertion of a double-J-shaped stent with or without suturing over the stent.[82] The stent should be left *in situ* for 6 weeks to aid urinary diversion and promote healing. If the ureter is completely transected with no loss of ureteric length and the site of the injury is less than 5 cm from vesicoureteric junction, re-implantation of the ureter directly into the bladder is usually performed, preferably with tunnelling of the ureter through the bladder muscularis to avoid ureteric reflux, and recurrent urinary tract infections. If the injury is more than 5 cm from the bladder, this can generally be re-anastomosed by uretero-ureterostomy.[84] Where there is a loss of ureteric length, a psoas hitch or Boari flap may be considered to ensure a tension-free anastomosis.

Patients with delayed ureteric injuries may present with a variety of symptoms in the postoperative phase. These include loin pain secondary to hydronephosis/ureteric obstruction, haematuria, oliguria, urinary incontinence in cases of ureterovaginal fistulas, hypertension from obstructive nephropathy, ileus, peritonitis or sepsis. Serum biochemistry may reveal rising serum creatinine due to re-absorption of urine transperitoneally. Fluid aspirated from intra-peritoneal or retroperitoneal collections can be analysed for similarity to urine osmolality.

Ultrasonography, an IVP and CT with intravenous contrast may demonstrate the presence of hydronephrosis or hydroureter, free fluid in the retroperitoneal or intra-peritoneal spaces or intraperitoneal contrast due to urinary leakage. Cystoscopic visualisation of ureteric jets into the bladder can be falsely re-assuring in case of incomplete or delayed ureteric injuries. Retrograde ureterogram

involving injection of contrast up into the ureters via a cystoscope can be used to diagnose more subtle ureteric injuries not evident on IVP or CT studies.

In cases of suspected fistula formation, methylene blue can be instilled into the bladder. Vesicovaginal fistula may be diagnosed on the basis of finding blue dye staining of a tampon placed in the vagina. A ureterovaginal fistula may be confirmed when seeing intravenous pyridium producing an orange stain on a tampon in the vagina.[84]

Once ureteric injury is recognised, corrective surgery should be performed immediately (Table 5). If surgery is contraindicated due to severe infection or tissue necrosis, a percutaneous nephrostomy or retrograde stent placement should be performed to maintain urinary drainage and promote spontaneous healing.

Nerve injuries

Incidence

Nerve injuries are rare in laparoscopic surgery. However, the potential risk of neurological complications is generally related to the complexity and invasiveness of the procedure being performed. A study showing data collected from a gynaecological oncology fellowship programme found the general incidence rate of nerve injury was 1.9% and was highest (5.5%) during radical hysterectomy.[85]

Mechanisms of injury

Nerve injury related to laparoscopy can be due to stretching from improper patient positioning, excessive tissue retraction, nerve compression or direct injury during dissection.[86,87] Positional nerve injuries can occur in the upper and lower limbs. Brachial plexus injuries are the most common positional nerve injury and are usually the result of positioning the patient with outstretched arms and shoulder braces for a long duration of time.[88] Ulnar and peroneal nerve injuries are also related to positioning.

Neurological damage during pelvic surgery usually involves injury to one of the branches of the lumbosacral plexus. This includes iliohypogastric, ilioinguinal, genitofemoral, lateral femoral cutaneous, femoral, obturator, pudendal and sciatic nerves.[86] Table 6 presents the mechanism of nerve injury and resulting postoperative clinical manifestation.[86,88]

Prevention

Since the treatment of nerve injury is quiet difficult and is associated with unpredictable outcomes, prevention is the most crucial step in dealing with laparoscopy-associated nerve damage. Proper positioning of the patient in the low lithotomy position using boot stirrups is obligatory for every laparoscopic procedure.[86,88,89] This includes mild flexion of the hip to around 170° in relation to the trunk and 90°–120° flexion of the knee. Abduction of the thighs should result in no more than 90° between the legs, and there should be minimal external rotation of the hips. The patient's arms should be adjacent to the body.

Table 5
General principles of ureteric repair.[84]

1. Tension free anastomosis by ureteric mobilization
2. Ureteric dissection preserving adventitial sheath and its blood supply
3. Minimal use of fine absorbable suture to attain watertight closure
4. Use of peritoneum or omentum to surround the anastomosis
5. Drain the anastomotic site with a passive drain to prevent urine accumulation
6. Stent with a ureteric catheter
7. Consider a proximal diversion

Table 6
Mechanism of nerve injury and resulting post-operative clinical manifestation.

Nerve	Common mechanism of injury	Clinical manifestation
Femoral	Prolonged hip flexion, abduction, and external rotation Compression by retraction Direct injury	Impaired abduction and outward rotation of the hip Impaired extension of the knee Loss of patellar reflex Paresthesia over the anterior and medial thigh Paresthesia over the medial aspect of the calf
Lateral femoral cutaneous	Prolonged hip flexion, abduction, and external rotation Compression by retraction Direct injury	Paresthesia and pain in the proximal lateral thigh (meralgia paresthetica)
Genitofemoral	Direct injury during pelvic lymphadenectomy or removal of a pelvic sidewall mass	Paresthesia of the ipsilateral mons, labia majorum, and skin overlying the femoral triangle
Obturator	Prolonged hip flexion and abduction Direct injury during retroperitoneal dissection or paravaginal repair	Sensory loss in the upper medial thigh Impaired external hip rotation
Sciatic	Prolonged extension of the hip and flexion of the knee Direct injury during extensive laparoscopic pelvic floor repair or during hemostasis	loss of sensation over the calf and on the dorsum, sole, and lateral side of the foot Inability to flex the knee Drop foot
Iliohypogastric & ilioinguinal	Direct injury by extended Pfannensteil incision or Maylard incisions and nerve entrapment during suturing	Pain and anesthesia over the pubis, labia or thigh

Knowledge of anatomy is the key to avoid nerve injury during pelvic surgery, especially when performing retroperitoneal dissection for lymphadenectomy, the excision of deep infiltrative endometriosis or pelvic floor repair. It is also crucial for performing 'nerve sparing' surgery.

During laparoscopy both surgeon and assistant should be aware of the extent and duration of tissue traction and retraction which may include nerve fibres to avoid unnecessary damage from prolonged and excessive nerve stretching or compression.

Management

If neurological damage is suspected the patient should be examined for any kind of sensory or motor deficit, especially those that are related to the lumbo-sacral innervation. Early management is the key principle for success as is the case with most other types of injuries during laparoscopy. Symptom resolution can be very slow and incomplete at times. Success usually depends on the type of nerve, the extent of injury and the mechanism of injury.[88]

If injury has been identified during laparoscopy, attempts should be made to repair the injury with microsurgery, especially in cases of transection. This can be done by performing an epineural or a fascicular repair, preferably with the aid of a neurosurgeon.[90] Both nerve ends must be properly aligned and repaired with a minimal amount of 8/0 to 10/0 nylon sutures under magnification. If nerve injury has been identified after the procedure or if the mechanism of injury was a result of crushing or extreme pressure on the nerve, a non-invasive approach is usually required.

The femoral, obturator and sciatic nerves have a motor neuron component[86] and require initiation of physiotherapy as soon as possible as to avoid muscle atrophy. Sensory nerve injury is usually treated pharmacologically with oral analgesics, vitamin B supplements or low-dose tricyclic antidepressants.[86,88] The anti-epiletic medications, gabapentin and pregabalin, can also be used in doses of 900–3600 mg day^{-1}.[88] For long-term relief, corticosteroids and nerve blocks can be used. If this is not successful, surgical neurolysis, neuroma resection or nerve resection may be required.[91–94] In case of numbness without discomfort, the patient should be reassured.[88] Prognosis for symptom resolution is more favourable for sensory than motor nerve injury.[85]

Phase V – Communication and counselling

Communication and counselling are integral to the management of complications associated with surgery in general, and with laparoscopic surgery in particular because of the inherent perceived minimal invasive nature of this surgical approach. Taking patient's concerns seriously, acting on the concerns promptly, explaining the circumstances surrounding the complication fully, answering any questions related to the complication honestly, supporting the patient sympathetically and keeping the patient's relatives informed are important aspects in the management of complications in laparoscopic surgery.[11,95]

Conclusions

Complications are an inevitable part of surgery. Due to the rapid introduction of new technologies and techniques into laparoscopic surgery, awareness, teamwork, training, communication and counselling are essential aspects of risk management to ensure patient safety. When complications arise, a systematic and coordinated response is required to correct the injury promptly, to offer explanation and support to the patient fully, and to identify the 'errors' or 'lessons' from which strategies can be introduced to prevent or deal with similar complications appropriately.

Practice points

- Major complications during laparoscopy are rare but can be catastrophic.
- Prevention of such laparoscopic injuries can be maximised by careful appropriate laparoscopic surgical training, patient selection, greater understanding of anatomy and energy sources available to the surgeon, planning of surgery and building a regular and committed team which includes not only the anaesthetist, but also theatre practitioners (scrub nurse, surgical assistant and theatre runner). Most importantly, communication between the surgeon and the team intra-operatively is paramount.
- Predetermined systematic plans of action must be in place in the event that a complication occurs during laparoscopy. Systematic drills to deal with for example a major vascular injury should be regularly rehearsed in an animal laboratory environment in order to maintain team skills.
- Most vascular injuries occur during the laparoscopic entry phase before the introduction of the primary port.
- While Veres needles and primary trocar entries are the most common causes of major vascular injuries, vessel lacerations have also been reported with the Hasson open entry and direct entry techniques.
- Mortality from laparoscopic-induced bowel injury is as high as 3.6%.
- Laparoscopic urinary tract injuries range from 0.05% to 8.3%. Bladder trauma occurs more frequently than ureteric and is more readily recognised at the time of injury.
- Nerve injuries are rare in laparoscopic surgery.

Research agenda

- What is the optimal laparoscopic entry technique? An urgent randomised controlled trial (RCT) is needed to answer this clinically relevant issue. The main problem is that such a study would require a large denominator in order to demonstrate significant differences between complication rates of Veres needle versus Hasson entry techniques.

- Do regular vascular drills in an animal laboratory setting really make a difference in the real-life operating-theatre setting? Prospective comparative studies before and after such drills assessing clinical outcomes of intra-operative vascular injuries have not been done to date.
- Do laparoscopic skills training courses make a difference to the performance of delegates on return to their own operating-theatre working environments? Do they reduce subsequent complication rates?
- New developments in trocar equipment to reduce entry-related complications need to be prospectively evaluated.
- A national database to report complications secondary to laparoscopy should be set up in each country. This would encourage the reporting of laparoscopic complications and in turn enable valuable extraction of data including the true prevalence of vascular-related laparoscopic injury.

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